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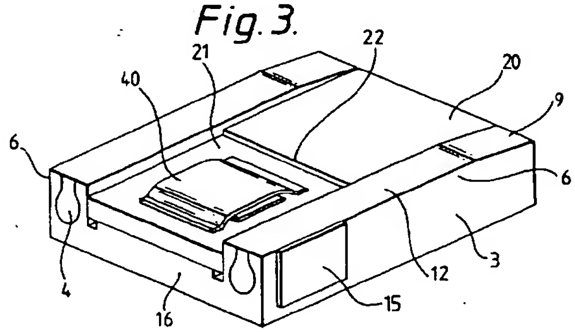
(54) Slider units for information recording devices and methods of making them.

(57) A slider unit having a reading/reproducing head (4), for use floating over the surface of an information recording disk, has a slider body having a flying height sensor (15), float surfaces on the underside thereof to generate a lift force, and a device (40) for controllably adjusting the lift force generated at the undersurface. Device (40) may be for example a piezoelectrically or electrostatically controllable valve layer positioned over a vent communicating between the upper surface of the slider and opening into a recess (21) for generating a negative lift component at the underside of the slider. The slider body is made from a ceramics base portion (3) and a semiconductive insert portion (20) e.g. of silicon or photosensitive glass, on which the adjustment device (40) can be formed using microfabrication techniques such as deposition and etching. A step (22) for forming a negative pressure generating recess (21) may also be etched in the semiconductive insert (20). By using these techniques, mass-production of the slider units is facilitated.

Fig. 3.



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This invention relates to slider units which are used to carry a reading/reproducing head at the surface of an information recording medium such as a disc. In other particular aspects it relates to methods of making such slider units, and to their use in information recording devices.

The concept of head-carrying slider units which float in near-contact against a disc surface, subject to a lift force generated by frictional air movement due to the relative movement of slider and disc, is well known from the prior art. They have been applied in information recording devices for use e.g. as external memory for information processing apparatus such as computers and word processors. A recording medium used is typically a magnetic or optical disc, although other media may also be used.

A typical slider unit for carrying the reading/reproducing head - typically a magnetic head or optical head - is formed with an air bearing structure on that side which faces the medium in use (hereinafter called the "float side"). Air passing between the float side and the medium generates a lift force on the slider unit. Usually the slider unit is mounted at the end of an arm which can exert a force towards the medium to counterbalance the lift force, to achieve a stable floating condition with a small gap (referred to hereinafter as the "flying height") between the slider unit and the medium surface.

It is generally recognized that the flying height should be kept as small as possible, indeed approaching zero, so as to maximize the information density that can be recorded on/reproduced from the information medium. For example, the flux from a magnetic recording head diverges away from the head and so the necessary area for one bit of information increases with increasing distance of the head from the medium. Accordingly, various proposals have been made to reduce the flying height to distances of the order of a few tens of microns (μm) and less.

The technical problem of controlling the flying height under these conditions is extreme. A typical slider unit may weigh several tens of mg and must be supported at an infinitesimal spacing from a fast-moving medium e.g. a disc rotating at several thousand rpm. Furthermore, the variation in this tiny spacing must be rigorously minimized.

The prior art contains a number of proposals for reducing and stabilizing the flying height.

JP-A-63/94479 describes a piezoelectric actuator for exerting a controllable downward force at the supported end of the load arm on which the slider unit is mounted. A sensor determines the flying height of the slider unit and the piezoelectric element responds to variations therein with a correcting force on the load arm. However the response is found to be slow, and the controllability of flying height variation is therefore poor.

JP-A-62/167681 describes a slider unit having a cavity on the float side between the "rails" for generating the positive lift. A metal or plastic insert between the rails has a thin limb on which a sub-slider including the head is mounted. The sub-slider is thus freed from the inertia of the main slider, and its flying height controlled either by selection of the springiness of the thin limb, or by making the thin limb a piezoelectric actuator whose angle can be adjusted in response to a flying height measured from the sub-slider. We have found that it is very difficult to keep the flying height to a steady level using such a construction.

Both the above sliders are "positive pressure sliders" in which the force generated at the float slide predominantly pushes the slider away from the medium surface. "Negative pressure" sliders have also been proposed, in which the slider conformation also produces a negative lift component towards the medium surface. Usually this is done by having a recessed section of the float side into which air passing the float side expands e.g. past a rearwardly-facing step on the float side. The recess is usually provided between side rails which generate the positive lift component. The negative component produces a tendency towards the medium surface at the slider unit itself and hence a better response characteristic. It is preferable when very high information recording density is sought. The downward force applied to the load arm can be reduced, which extends the life of the medium and slider particularly in a "contact start or stop" type in which the slider rests against the medium when not operating. In a non-contact start and stop type, the negative pressure component can improve the "self-loading" i.e. the initial approach movement made by the slider unit towards the medium surface and a steady floating state.

JP-A-63/21272 describes a slider having a negative pressure generating recess. Control is proposed using a vent hole bored through from the negative pressure pocket to the top surface of the slider, and a piezoelectric flap lying over the top surface of the vent hole. Piezoelectric control of the flap acts like a valve on the vent hole and regulates the negative pressure and hence flying height. In an alternative proposal, a transverse rail forming a step at the front of the negative pressure generating recess is made of piezoelectric material so that its height can be adjusted to adjust the negative lift.

US-A-4853810 describes a slider unit having a special tunneling electrode adjacent the head, seeking to achieve a very fine control of flying height at the head. Figure 6 of this document shows schematically an aerodynamic wing on the slider unit, which it is suggested could be made by microfabrication technology. However no information is given about the actual manufacture of this wing, its shape, control or position on the slider unit. No possible implementation of microfabrication is proposed.

It is generally true of the above documents that they do not consider the manufacturing methods that can be used to make the various control devices proposed. It is important to consider that the body of the slider unit is typically made of a hard ceramics material such as zirconia because the surfaces thereof which may contact the recording medium must be very hard and flat. These materials are difficult to machine and it is difficult to bond parts to them, particularly small parts.

A first problem addressed by the present invention is to provide a novel construction of slider unit. A second problem addressed is to provide the construction so that it can be mass-produced relatively easily while still enabling control of flying height. A further problem addressed is that of providing new production methods for such slider units.

According to the invention, a mechanism, device for conformation for controlling flying height is formed in an integrated manner on a piece of semiconductive material e.g. silicon or photosensitive glass. Choice of materials susceptible to microfabrication enables this to be done easily using e.g. deposition and etching techniques of a known nature, and also makes possible the mass production of many such devices on a wafer of the material. The piece of semiconductive material incorporating the lift adjusting formation is then fixed to another part or parts to make up the slider body with the semiconductive substrate piece comprised therein.

In one specific aspect, the invention provides a slider unit comprising a slider body and a reading/reproducing head, for operation at the surface of an information recording medium moving relative thereto, whereby air movement between a float side of the slider unit and the surface of the medium causes a lift force on the slider unit, and further comprising an adjustable element for adjusting the lift force on the slider body, characterized in that

the slider body comprises a substrate portion of semiconductive material, and the adjustable element is integrally formed thereon.

Preferably, a sensor for measuring the flying height is also comprised in the slider unit e.g. on the slider body.

One preferred application of the technique is in a negative pressure slider in which the slider body has a recess on the float side as described above. This recess can be formed partially or entirely in the semiconductor substrate material thus facilitating its formation. For example, the semiconductive material may be formed with a step which is at one limit e.g. the forward end of the negative pressure generating recess. Side limits of the recess may likewise be formed in the semiconductive material, or they may be defined in the assembled slider body by side portions of the basic body material (usually ceramics) which project towards the float side. Typically these are side rails having float side surfaces for generating positive lift force.

A variety of adjustable means may be provided for controlling the lift, using the easier fabrication afforded by the use of the semiconductive substrate or insert. In one version, a slider unit having a negative pressure generating recess as described also has a vent communicating from the recess on the float side to the exterior at another part of the slider body e.g. the opposite side.

A valve element for controlling flow through the vent is provided by being formed on the semiconductor substrate. The valve element may be a bridge or cantilever layer, extending over an opening of the vent so that it can wholly or partially close it off, preferably on the float side. Such valve members may be formed on the semiconductive substrate by a deposition and etching technique in a known manner. To enable its control by electrical means, it may be a multi-layer construction forming a piezoelectric or electrostatic actuator.

To reduce disturbance of air flow, such a valve member may be itself be recessed into the surface of the semiconductive piece at the vent opening. It may be then substantially flush with the surrounding surface.

There are various ways in which a microfabricated movable layer construction of the semiconductive substrate can be used to control lift.

Another possibility is a controllably movable wing or vane on the semiconductive substrate. Again, this is preferably provided on the float side and may be associated with a negative lift generating recess. It may enable variation of the negative pressure generated by the recess e.g. by enabling variation of the height of a step at the front of the recess. Alternatively or additionally, it may itself be able to generate a positive lift component by being positioned towards the rear of a negative pressure generating recess, or at some other portion of a slider.

Usually, the vent will include a hole through the semiconductive substrate itself.

In view of the above, we provide in a further specific aspect a slider unit for operation at the surface of an information recording medium moving relative thereto, whereby air movement between a float side of the slider unit and the medium causes a lift force on the slider unit, the unit comprising a slider body and a recording/reproducing head, with a vent being provided through the slider body (1) from the float side, characterized in that

means for adjustably controlling the degree of opening of the vent is formed on a semiconductive substrate comprised in the slider body .

In a further specific version, we provide a slider unit for operation at the surface of an information recording medium moving relative thereto whereby air movement between a float side of the slider unit and

the medium causes a lift force on the slider unit, the slider unit having a slider body and a recording/reproducing head, a recess being provided on the float side to create a negative lift component, and means being provided on the float side to adjust the lift force in response to information from a flying height sensor comprised in the slider unit,
characterized in that

the slider body comprises on the float side an insert portion of semiconductive material which is shaped on the float side to provide said recess and which carries said means for adjusting the lift force.

In a still further aspect, we provide a slider unit comprising a slider body and a recording/reproducing head for floating operation at the surface of an information recording medium which moves relative thereto, the slider body having a float side which faces the surface of the medium in use, and comprising

a ceramics portion with a central part and side rails which extend longitudinally along opposite edges of the central part and project to the float side, and a semiconductive insert portion fixedly bonded to the ceramics portion on the float side between the side rails thereof, the float side surface of the fixed semiconductive insert portion being provided with at least one integrally formed and etched lift force control formation.

Accordingly, a generally conventional slider conformation having a main ceramics substrate with a central part and side rails can complement a semiconductive insert formed in accordance with the above teachings, to provide a composite construction in which the hardness of the ceramics material provides the desired properties at the extremities on the float side, while the susceptibility of the semiconductive insert to microfabrication enables the provision of sophisticated lift control means.

The ceramics portion may be e.g. zirconia, titania or alumina based ceramics.

A slider unit according to any one of the aspects explained above may be mounted on an arm of an information recording device, in a manner which is generally conventional. Such an information recording device is provided as a further aspect of the invention.

In another aspect, we provide a method of making a slider unit which has a slider body and a recording/reproducing head, for use at the surface of an information recording medium moving relative thereto whereby air flow between a float side of the slider unit and the medium causes a lift force on the slider unit, and which further comprises an adjustable element for adjusting said lift force in response to sensed flying height of the slider body;

the method being characterized by forming said lift adjusting element on a semiconductive substrate and fixing the semiconductive substrate to a base substrate to form the slider body.

As has been explained, this method is susceptible of implementation by using conventional microfabrication techniques such as thin-film deposition, fine pattern exposing, and forming using anisotropic and/or isotropic etching techniques. A skilled man will know how to use these techniques to make e.g. piezoelectric and electrostatic actuators in the form of movable flaps or bridges on a semiconductive substrate.

Similarly, the formation of steps and/or other recesses in the surface of such a semiconductive substrate is a straightforward matter using conventional etching/masking methods.

Most desirably, the method is implemented in a mass-production régime. In this respect, we provide a methods of making a plurality of slider units each having a slider body and a recording/reproducing head, for use at the surface of an information recording medium, and each comprising a control element for modifying a lift force generated in use between a float side of the slider body and the medium, characterized by

forming an array of said control elements on a parent piece of semiconductive material;

sub-dividing the parent piece into plural substrate portions each formed with a said adjustable element, and fixing respective said substrate portions to respective ones of plural base substrates to form said slider bodies.

The base substrates, usuâlly made from ceramics material, can be formed by forming an array of recording/reproducing heads on a parent piece of base substrate material;

sub-dividing the parent piece into plural base substrate precursors, and

shaping the base substrate precursors to form the base substrates.

As described above, the control element may comprise a piezoelectric unimorph or bimorph, or an electrostatic actuator.

To fix the semiconductive substrate to the base substrate, which is usually of ceramic material, methods such as brazing or anode bonding may be used. It is preferable that the bonding temperature be 250°C or lower. Inorganic or metallic material may be used for bonding.

It will be appreciated that the method as described can avoid the need for carrying out complex shape-forming on a relatively unmachinable material such as zirconia ceramics. Furthermore, since the delicate control mechanism can be formed by microfabrication techniques which are well adapted to forming micro-scale formations, but can be made on a semiconductive substrate of significant size which is easily handleable, it is no longer necessary to bond a very small adjustment or control mechanism to a ceramic slider body. The bonded part and its bonding surface can be larger and simpler than previously pro-

posed, making assembly more easy.

In a further aspect, we provide a method of controlling a slider unit in operation at the surface of an information recording medium, in which the slider unit is as set out in any of the aspects above.

The preferred flying height may be as little as 0.1 μm or less, even as low as 0.05 μm or less. At 0.1 μm, it should be possible to achieve an information recording density of 5 x 10^5 bits/mm^2, and so preferably an information recording density of at least this value is achieved.

Embodiments of the invention are now described by way of example, with reference to the accompanying drawings in which:

Figure 1 is a schematic view of an information recording device comprising a slider unit;

Figure 2 is a longitudinal cross-section at A-A' of the slider unit shown in Figure 1, showing a general construction of the body thereof;

Figure 3 is a perspective view in detail of the float side of a first embodiment of the slider;

Figure 4 is a longitudinal section through an electrostatically-actuated control valve of the Figure 3 embodiment;

Figure 5 is a corresponding cross-section of a variant using a piezoelectric actuator;

Figure 6 shows a second embodiment using a cantilevered control valve, with part of the slider body sectioned for clarity;

Figure 7 shows in longitudinal cross-section the cantilevered control valve of the second embodiment, using an electrostatic actuator;

Figure 8 shows a variant using a piezoelectric actuator;

Figure 9 is a perspective view of the float side of a third embodiment of slider unit using a movable wing to vary a negative lift component, the view being partly transversely and longitudinally sectioned for clarity;

Figures 10 and 11 show constructions for such a movable wing using an electrostatic actuator and a piezoelectric actuator respectively;

Figure 12 is a view corresponding to Figure 9, of a fourth embodiment using a movable wing for generating a positive lift component, and

Figures 13 to 15 show steps in a method embodiment wherein Figure 13 shows preparation of ceramics base substrates, Figure 14 shows preparation of semiconductor inserts, and Figure 15 illustrates assembly of the base substrates and inserts.

With reference to Figure 1, an information storage device comprises a negative pressure slider 1 supported by a load arm 5 over the surface of a magnetic or optical disc 7. The disc 7 is mounted rotatably on a driving shaft 8. Radial positioning of the slider 1 relative to the disc is done in a conventional manner by an actuator 6 such as a voice coil motor or a piezoelectric element.

When the disc 7 is rotating at operational speed, air carried along by frictional engagement with its surface passes between that surface and the slider 1, generating a lift force between them which holds the slider floating above the disc surface.

Figure 2 shows the general shape of the slider body 1 in longitudinal cross-section. The end of cantilevered load arm 5 is seen, fixed to the top surface of the slider body. The bottom or float surface 10 of the slider body has a general conformation which can be seen in more detail from Fig. 3 which shows the slider body inverted.

The body consists essentially of a ceramics main body 3 e.g. of zirconia based ceramics, having a general downward-facing channel shape, and an insert substrate 20 made of silicon which is fixed in the channel opening of the main body 3. More specifically, the main body 3 comprises a flat central portion 16 with integral downwardly-projecting rail portions 6 extending along each side thereof for substantially the full length of the body. The downwardly-facing surface 12 of each rail 6 is machined very flat and smooth, and forms a positive lift-generating surface for the body. At its front end, each surface 12 has a forwardly and upwardly inclined portion to assist in generating the lift force.

At the rear end of each of the side rails, a recording/reproducing head 4 is integrally formed. In this embodiment, each head 4 is a magnetic head whose construction is conventional in this art and need not be described further. The head extends, as again is conventional, to the lowermost extremity of the rail 6 of the float side, so as to be as near as possible to the recording medium in operation.

The semiconductor insert 20 occupies the full width of the channel formed between the two rails 6. It also extends the full length of the slider body. In the embodiment shown it is a rectangular piece having a flat upper surface bonded to the opposing flat surface of the main body centre 16 by anode bonding. A brazing or soldering fixing may be used. The lower surface of the insert 20, on the float side, is also generally flat but has a substantial recessed portion 21 at its rear part, occupying about half its length, creating a transverse perpendicular step 22 in its middle region. The step may appear towards the forward end of the slider if desired. In operation, air passing between the slider float side and the medium surface, and between the rails 6, expands upwardly into the recess 21 as it passes the transverse step 22, causing a reduction in the pressure of the air and a downward force component at this part of the slider.

A flying height sensor 15 is attached to a side surface of the slider body. This is a measuring instrument which may be, for example, of a capacitance detection, optical or ultrasonic type. Such sensors and their construction are known to the man skilled in the art.

In this context, the use of a very small integrated-type measuring instrument manufactured using semiconductor fabrication technology is preferred.

Means for effecting controlled and adjustable variation of the lift force is provided on the semiconductor insert 20, and a first embodiment of such means is described with specific reference to Figs. 3 and 4.

A cylindrical vent hole 9 is formed through the central layer 16 of the ceramics body 3, downwardly from the top surface 11 thereof, and is in register with a corresponding hole through the semiconductor insert 20 formed generally in the centre of its recess region 21. Through the semiconductor layer 20, vent hole 9 tapers to a small opening at the float side.

A control microvalve 40 is formed on the surface of the semiconductor insert 20 at the opening of the vent 9.

Microvalve 40 comprises a flat layer of an electrostatic actuator, spaced a short distance above the opening of the vent 9. Figure 4 shows the construction in more detail. The actuator has a bridge structure rooted on opposite sides of the vent opening, with a fixed electrode layer 43 deposited around the end opening and having a corresponding hole, and a movable layer spaced above the fixed electrode 43 by a thin laminar gap 45 and comprising an insulating layer 42 on the inside and a further electrode layer 41 on the outside. Each of these layers, and the gap, is preferably 1 to 10 μm thick. The electrodes 41,43 are preferably thin films of metals or sufficiently conductive semiconductive materials e.g. Al, Ag, Au, Ti or Si. The movable insulating layer 42 is preferably of a ceramics-type layer e.g. SiO_2, Si_3N_4, Al_2O_3 or plastics e.g. polyimide.

These thin films are made by sputtering, evaporation, chemical vapor deposition (CVD) or plating techniques. Then, they are subjected to light exposure and etching processes to create the desired pattern. These techniques are generally known and can be referred to as microfabrication techniques. The vent opening through the monocrystalline silicon insert 20 and fixed electrode 43 can be made by anisotropic etching. The gap 45 is created by the known technique of sacrificial etching in which a layer initially deposited is then removed by etching from the exposed edge thereof.

Lead wires are connected to the movable and fixed electrodes 41,43 by soldering or, more preferably, ultrasonic bonding. Figure 4 shows a connection location 41a for the movable electrode 41. These can then be connected to a DC supply installed on an external mount. DC voltage applied across the two electrodes causes an electrostatic attractive force between them and closes the opening to the vent 9 either completely or to a degree depending on the applied voltage. By closing the vent 9, the negative lift component generated by recess 21 is maximized. Consequently, microvalve 40 provides a means for controlling in a smoothly adjustable manner the exact amount of lift. It can be connected in a closed-loop feedback system including the sensor 15 so that a desired flying height is maintained in operation. That is, the flying height is monitored at all times by the sensor 15. If the flying height becomes larger than a predetermined reference height (for example 0.1 μm) deemed optimal for information recording/reproduction, a DC voltage initially applied across the microvalve electrodes 41,43 is reduced so that it ceases to close entirely the vent 9. The degree of voltage reduction is determined by the measured difference between the measured and pre-set flying heights. The resulting air flow in vent 9 influences the negative lift to the desired degree (which can be determined by calibration) and adjusts the flying height continuously towards the desired reference level. A control circuit connected to the DC supply enable the closed-loop control.

Figure 5 shows a variant form of microvalve 50. In this variant the vent 9 is formed as before, but the microvalve 50 is piezoelectrically actuated. It comprises a movable bridge made up of three layers formed on the monocrystalline silicon substrate 20 by microfabrication. A top electrode layer 51 and a bottom electrode layer 53 are separated by an intermediate layer 52 of piezoelectric material. All three layers are integrated in the bridge structure and there is no fixed layer.

The electrodes 51,53 are connected to a DC supply as with the Fig. 4 version, using e.g. electrode bonding pad 51a. Application of voltage between the electrodes distorts the piezoelectric layer 52 and the bridge can move across the laminar gap 55 to close off the opening of vent 9 to the desired degree. Closed-loop lift control can be performed as described above.

The second embodiment is described with reference to Figs. 6 and 7. The slider body 1 and vent 9 are generally similar to those described in the first embodiment. However the microvalve movable member is different, being supported only at one side so as to form a cantilever. The construction is shown in section in Fig. 6, and in more detail in Fig. 7 where it is seen that the cantilevered microvalve member 60 forms an electrostatic actuator in a manner analogous to the bridge of Fig. 4. The construction and operation of the cantilever actuator 60 are also analogous to the Fig. 4 embodiment, but the cantilever version may have a larger distortion for a given applied voltage. This may widen the adjustment range of the lifting force.

A further feature shown in this embodiment is a local recess 23 formed in the general surface of the large recess 21 in the semiconductor substrate 20. Local recess 23 is only slightly larger than, and the same thickness as, the electrostatic actuator which is

formed in it in its rest condition. Consequently the microvalve actuator member 60 causes less disturbance of the air flow past the slider and this is preferable. The bridge embodiments of Figures 4 and 5 may similarly be formed in local recesses.

Figure 8 shows a variant analogous to Figure 5, in which the cantilevered microvalve member is a piezoelectric actuator 70, likewise formed in a local recess 23. The construction and operation of the piezoelectric actuator 70 are analogous to those described above.

Figure 9 shows a third embodiment, with longitudinal and transverse sections as in Fig. 6. The general construction of the slider body base 3 and semiconductor insert 20 are as before, except that the transverse step 22 of the insert 20 is displaced towards the front end i.e. about a quarter of the way back. Behind the step 22, the recessed insert surface 21 is flat. The lifting force adjusting mechanism is a movable wing 80 formed at the front of the slider body. This is formed by a generally rectangular deposited layer having an anchoring portion 81 at the front, covering the front non-recessed portion of the silicon insert 20, and a movable portion 82 extending rearwardly over the step 22 and at a narrow spacing above the surface of the recessed part 21. The free straight rear edge 83 of the wing terminates about half way along the slider.

Figures 10 and 11 show how such a wing may be made as an electrostatic actuator (Fig. 10) or as a piezoelectric actuator (Fig. 11). The electrostatic actuator can have a fixed electrode 86 formed under the wing on the opposing surface of the recessed silicon substrate 20. The wing itself can comprise the usual lower insulating layer and upper electrode layer as before. Operation is analogous to that described previously.

Similarly, Fig. 11 shows a piezoelectric version in which the wing-forming layer 80 comprises a piezoelectric layer 87 sandwiched between two electrode layers.

The flat construction of the wing layer 80 can be formed very simply by well-known techniques.

In this embodiment, no vent is provided through the slider body. When the wing 80 is deflected by application of voltage, the effective depth of the recess 21, relative to air approaching it over the wing 80, changes. Negative lifting force is increased if the recess is deepened, and decreased if it is more shallow.

A fourth embodiment is shown in Figure 12, again with sections to clarify the structure. The slider body is generally as before. In this case, however, the silicon insert 20 is formed with two transverse steps. The main transverse step is as before, defining the recessed portion 21 over about half the area of the insert 20. An additional step 24 extends transversely across the insert 20 about half way back along the main recess 21, defining a more deeply-recessed portion.

The lift adjusting member comprises a movable wing 90 projecting rearwardly from the second step 24 and having its free edge flush with the rear of the slider body, in register with heads 4. The wing 90 has a cantilever construction, spaced over the more deeply-recessed portion, which can be formed in the same way as those shown in Figs. 10 and 11. By changing applied voltage to move the wing 90 up or down, lift can be adjusted. In particular, by moving the free end of the wing away from the slider body towards the passing medium, a positive lifting force can be obtained and adjusted that acts at or adjacent the rear end of the slider body.

Methods of making the slider units are now described in more detail.

(1) Information recording/reproducing heads 4 of a conventional type are formed in the appropriate end portions of a ceramic main body substrate of a slider material e.g. a ZrO_2/TiO_2-based ceramic material. The head-forming process can be conventional.

(2) The slider material with the formed heads 4 is then machined into a base substrate 3 having the parts as shown in e.g. Fig. 3. The base substrate may be e.g. 2 to 4 mm long, 1.5 to 3 mm wide and 0.5 to 1 mm thick. If a venting adjustment is to be used, a vent hole is bored in the appropriate portion.

(3) A semiconductive substrate of silicon or photosensitive glass is provided with the desired lift modifying and adjusting components. For example, a recessed section 21 with its step 22 may be formed by anisotropic etching of monocrystalline silicon using e.g. a potassium hydroxide solution. An appropriate depth of recess may be 5 to 100 μm. By the etching method, a desired shape can be obtained with good precision and without the risk of forming fine cracks as would be likely to happen if machining methods such as cutting were used. A necessary air vent hole may be formed in a corresponding fashion. Microvalve and/or wing elements can be formed by the deposition/etching techniques described above. In particular, thin-film deposition methods such as sputtering, evaporation, CVD and plating, fine pattern exposure techniques, and anisotropic and isotropic etching techniques may be used.

(4) The semiconductor piece bearing the necessary lift control formation is cut to a chip about 2 to 4 mm long and 1 to 2 mm wide.

(5) The slider base substrate 3 and semiconductor chip 20 are bonded together to give the desired slider body with lift control means.

If a photosensitive glass is used for the insert part, anisotropic etching can be performed by UV irradiation of an exposed pattern which is to be etched. Irradiation causes a phase change rendering the exposed pattern vulnerable to wet etching giving the des-

ired formation.

Bonding of the semiconductor and base substrates may be as follows. An In-Sn alloy is sandwiched between the base substrate and semiconductor substrate under a pressure of 0.1 kgf/mm^2 at a temperature below 250°C, bonding them together. Alternatively, a low-melting point glass adhesive may be used, having a softening point around 250°C. A further embodiment uses a metal film formed on the junction surface of the main body substrate against which the semiconductor insert is pressed at a temperature of e.g. about 250°C, and with the application of several tens to several hundred volts between the two components. This achieves so-called anodic or voltage application bonding which uses electrostatic force to bond members having ion conductivity.

Figures 13 to 15 extend the concept to a mass-production method. Figure 13 shows schematically how a parent slab 203 of zirconia based ceramics is formed with an array of information recording/reproducing heads 4 which in themselves are conventional. The slab 203 is sub-divided to form a multiplicity of rectanguloid slider substrate precursors 103, each having a pair of the heads 4 as in the desired slider unit. Then, each of the precursors 103 is machined to form the desired channel-configuration with the side rails 6, shaped positive lift surfaces 12 and, if desired, the vent hole 9.

Figure 14 shows a circular standard wafer 120 of silicon or photosensitive glass. By etching and deposition techniques, the natures of which have been discussed above, an array of the desired lift control formations is created on the wafer 120. In the example shown, elongate recesses 121 are created by etching, simultaneously forming step formations 122 at their edges. In these long recesses, an array of through-holes for venting is created by further etching. Using techniques already described, an array of controllable microvalves 40 is made by deposition and etching technique over each of the vent holes.

This prepared wafer can then be cut into a multiplicity of chips 20 of an appropriate size, each of which has the desired recess portion 21 and microvalve 40 formed thereon and which is ready to be inserted into a corresponding base substrate 3 from the process of Fig. 13, and bonded thereto by means described above. Since the fine components and particularly the adjusting microvalve 40 are formed on an insert 20 which is inserted bodily in the bonding process, the risk of damage to the microvalve is greatly reduced since it need not be contacted in the bonding process.

Claims

1. A slider unit comprising a slider body (1) and a reading/reproducing head (4), for operation at the surface of an information recording medium (7) moving relative thereto, whereby air movement between a float side (10) of the slider unit and the surface of the medium causes a lift force on the slider unit, and further comprising an adjustable element (40-90) for adjusting the lift force on the slider body in response to a sensed flying height thereof,
characterized in that
the slider body (1) comprises a substrate portion (20) of semiconductive material, and the adjustable element (40-90) is integrally formed thereon.

2. A slider unit according to claim 1, further comprising a sensor (15) for measuring the flying height.

3. A slider unit according to claim 1 or claim 2 in which the slider body (1) has a recess (21) on the float side for generating a negative lift force component, and the recess (21) is formed at least partially in the semiconductive substrate (20).

4. A slider unit according to claim 3 in which the semiconductive substrate (20) has a transverse surface step (22) at a forward end of the recess (21).

5. A slider unit according to any one of claims 1 to 4 in which a vent (9) communicates through the slider body (1) from the float side (10), and the adjustable element is comprised in a valve member (40-70) for the vent, formed on the semiconductive substrate (20).

6. A slider unit according to claim 5 in which the valve member (40-70) comprises at least one layer formed on the semiconductive substrate (20) by deposition.

7. A slider unit according to any one of claims 1 to 4 in which the adjustable element comprises a controllably movable wing (80,90) projecting rearwardly on the float side (10).

8. A slider unit according to any one of the preceding claims in which the adjustable element (40-90) is piezoelectrically or electrostatically controllably movable.

9. A slider unit for operation at the surface of an information recording medium (7) moving relative thereto, whereby air movement between a float side (10) of the slider unit and the medium (7) causes a lift force on the slider unit, the unit comprising a slider body (1) and a recording/reproducing head (4), with a vent (9) being provided through the slider body (1) from the float side,

characterized in that

means (40-70) for adjustably controlling the degree of opening of the vent (9) is formed on a semiconductive substrate (20) comprised in the slider body (1).

10. A slider unit according to claim 9 in which the adjustable control means (40-70) for the vent opening comprises at least one layer formed by deposition on the semiconductive substrate (20) and forming a bridged or cantilevered valve member across the opening of the vent (9).

11. A slider unit according to claim 9 or claim 10 in which the valve member (40-70) is in a seating recess (23) formed therefor in the substrate (20).

12. A slider unit for operation at the surface of an information recording medium (7) moving relative thereto whereby air movement between a float side (10) of the slider unit and the medium (7) causes a lift force on the slider unit, the slider unit having a slider body (1) and a recording/reproducing head (4), a recess (21) being provided on the float side (10) to create a negative lift component, and means (40-70) being provided on the float side to adjust the lift force in response to information from a flying height sensor (15) comprised in the slider unit,

characterized in that

the slider body (1) comprises on the float side an insert portion (20) of semiconductive material which is shaped on the float side to provide said recess (21) and which carries said means (40-90) for adjusting the lift force.

13. A slider unit according to claim 12 in which the means for adjusting the lift force comprises a movable wing (80) projecting rearwardly over a step (22) defining the front of the recess (21).

14. A slider unit according to claim 12 in which the means for adjusting the lift force comprises a movable wing (90) projecting rearwardly over a second step (24) at the rear of the recess (21).

15. A slider unit comprising a slider body (1) and a recording/reproducing head (4) for floating operation at the surface of an information recording medium (7) which moves relative thereto, the slider body (1) having a float side (10) which faces the surface of the medium (7) in use, and comprising

a ceramics portion (3) with a central part (16) and side rails (6) which extend longitudinally along opposite edges of the central part and project to the float side (10), and a semiconductive insert portion (20) fixedly bonded to the ceramics portion (3) on the float side between the side rails (6) thereof, the float side surface of the fixed semiconductive insert portion (20) being provided with at least one integrally formed and etched lift force control formation (22,40-90).

16. A slider unit according to claim 15 in which the ceramics portion (3) comprises zirconia, titania or alumina ceramics, and the semiconductive portion (20) comprises a silicon or photosensitive glass substrate.

17. An information recording device comprising a slider unit according to any one of claims 1 to 16 mounted on an arm (5), and means (8) for driving an information recording medium (7) adjacent the float side (10) of the slider unit.

18. A method of making a slider unit which has a slider body (1) and a recording/reproducing head (4), for use at the surface of an information recording medium (7) moving relative thereto whereby air flow between a float side (10) of the slider unit and the medium (7) causes a lift force on the slider unit, and which further comprises an adjustable element (40-90) for adjusting said lift force in response to sensed flying height of the slider body;

the method being characterized by forming said lift adjusting element (40-90) on a semiconductive substrate (20) and fixing the semiconductive substrate (20) to a base substrate (3) to form the slider body (1).

19. A method according to claim 18 comprising forming the adjustable element by steps including thin-film deposition on the semiconductive substrate (20), and etching.

20. A method according to claim 18 or claim 19 comprising etching a transverse step (22) in the semiconductive substrate to form a recess (21) for generating a negative lift force component in the resulting slider unit.

21. A method of making a plurality of slider units each having a slider body (1) and a recording/reproducing head (4), for use at the surface of an information recording medium (7), and each comprising a control element (40-90) for modifying a lift force generated in use between a float side (10) of the slider body (1) and the medium (7), characterized by

forming an array of said control elements (40-90) on a parent piece (120) of semiconductive material;

sub-dividing the parent piece (120) into plural substrate portions (20) each formed with a

said adjustable element (40-90), and fixing respective said substrate portions (3) to respective ones of plural base substrates (3) to form said slider bodies (1).

22. A method according to claim 21, in which the base substrates (3) are formed by

forming an array of recording/reproducing heads (4) on a parent piece (203) of base substrate material;

sub-dividing the parent piece (203) into plural base substrate precursors (103), and

shaping the base substrate precursors (103) to form the base substrates (3).

23. A method according to any one of claims 18 to 22 in which the control element comprises a piezoelectric unimorph or bimorph, or an electrostatic actuator.

24. A method according to any one of claims 18 to 23 in which the semiconductive substrate (20) is fixed to the base substrate (3) by brazing or by anodic bonding.

Fig.1.

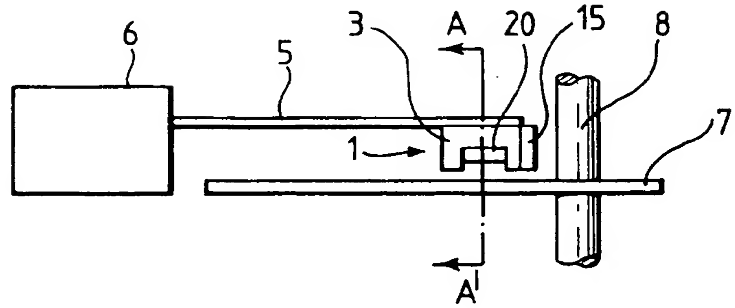


Fig.2.

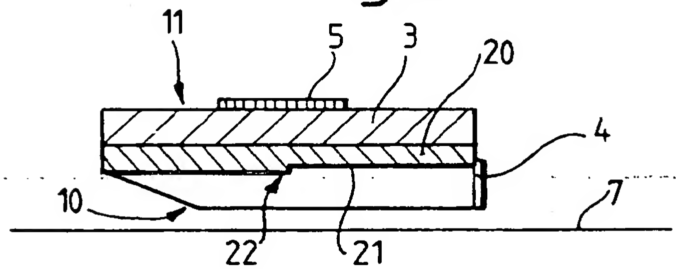


Fig.3.

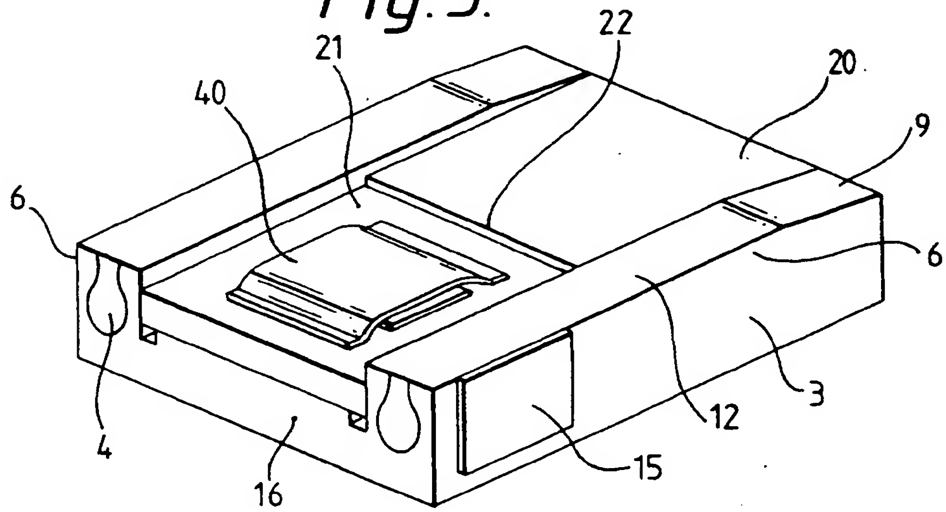


Fig.4.

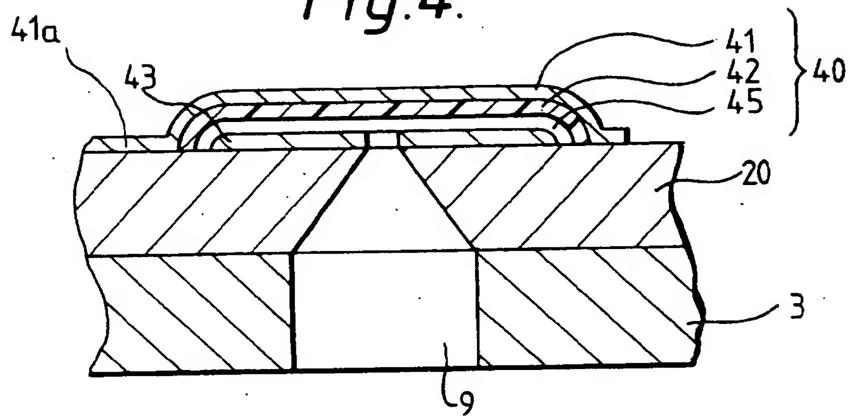


Fig.5.

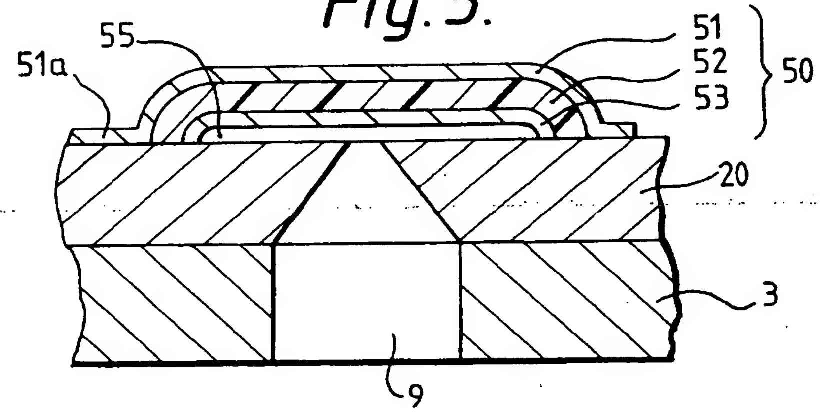


Fig.6.

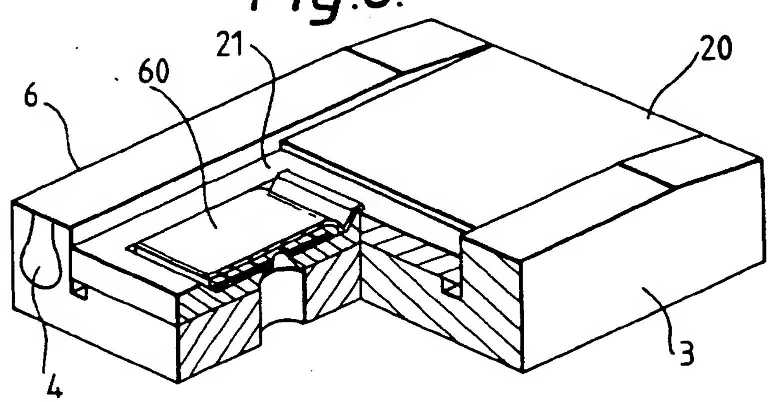


Fig.7.

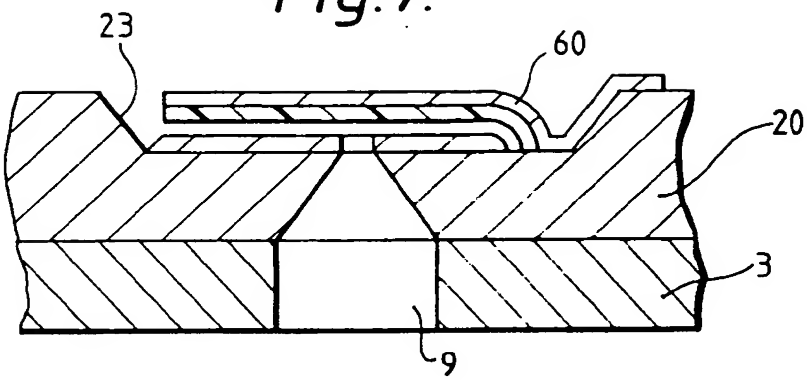


Fig.8.

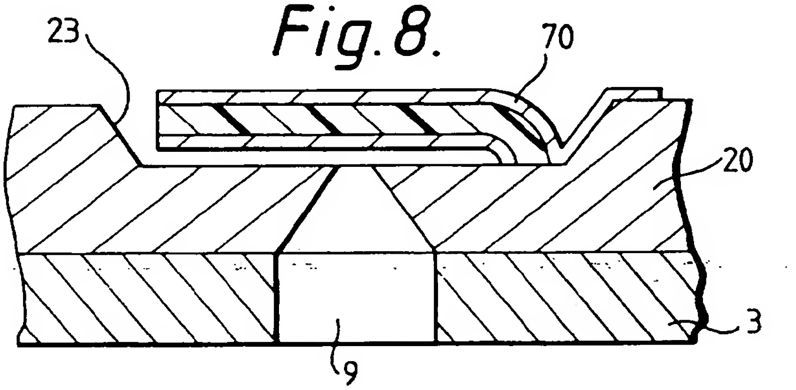


Fig.9.

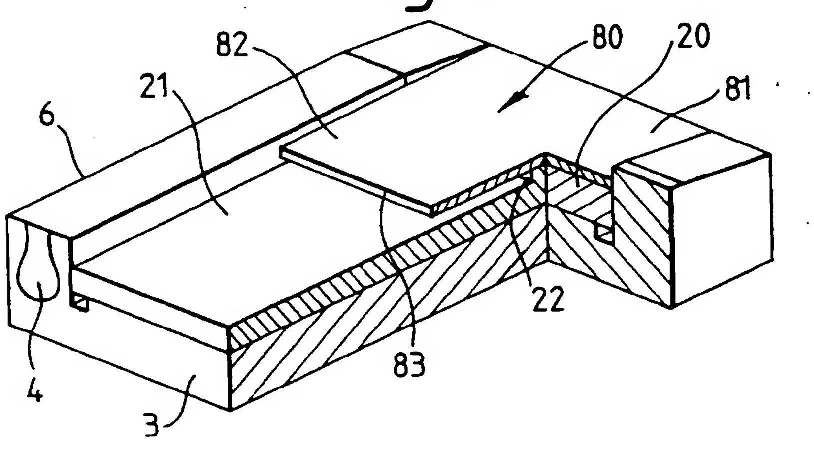


Fig.10.

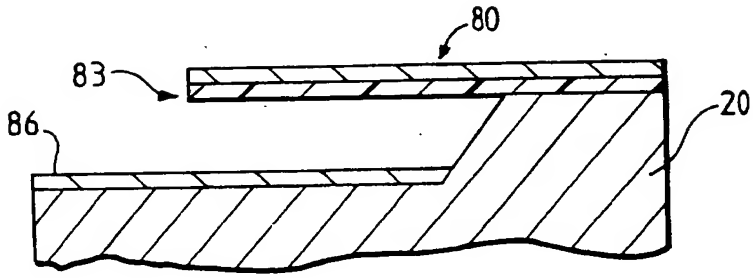


Fig.11.

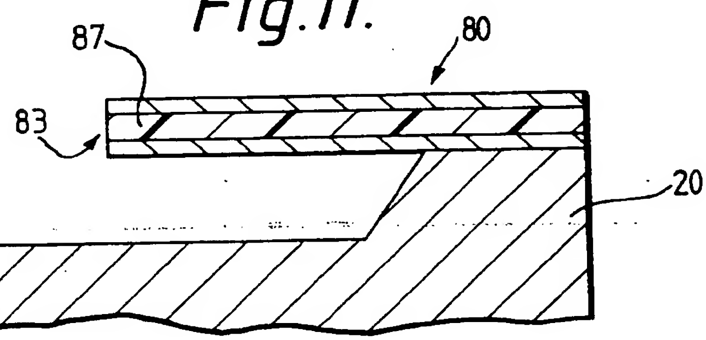
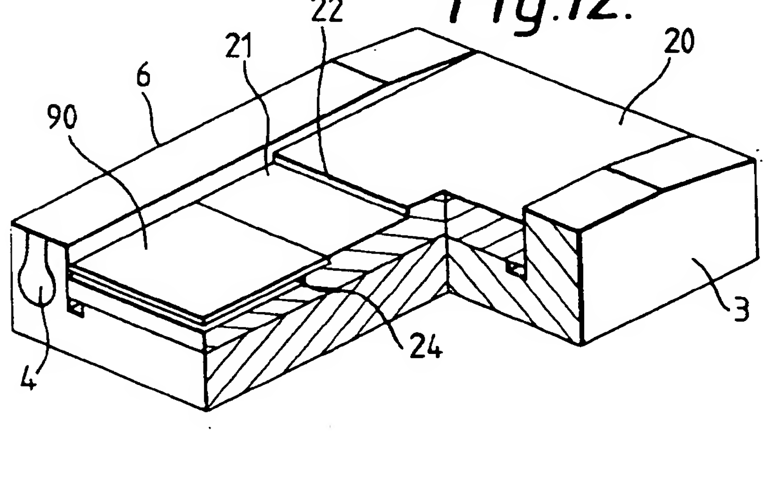


Fig.12.



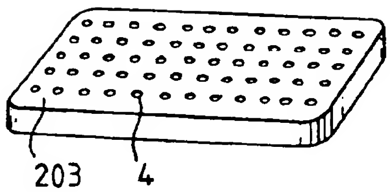


Fig.13a.

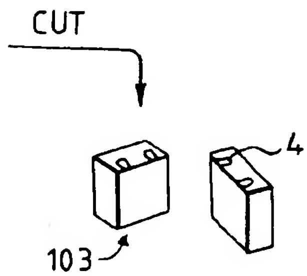


Fig.13b.

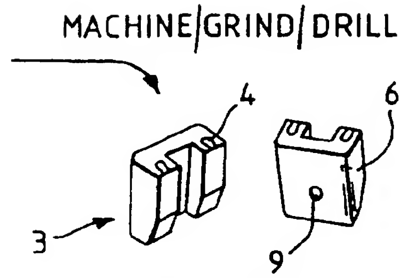


Fig.13c.

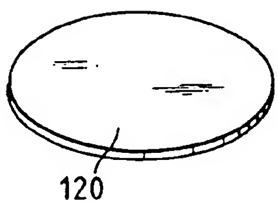


Fig.14a.

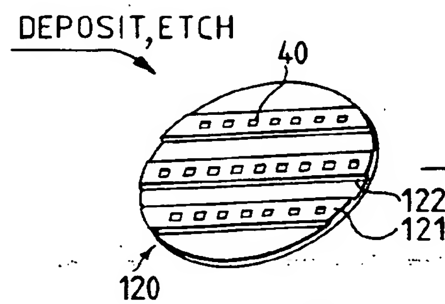


Fig.14b.

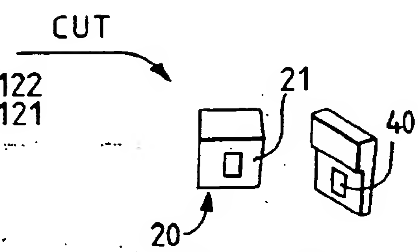


Fig.14c.

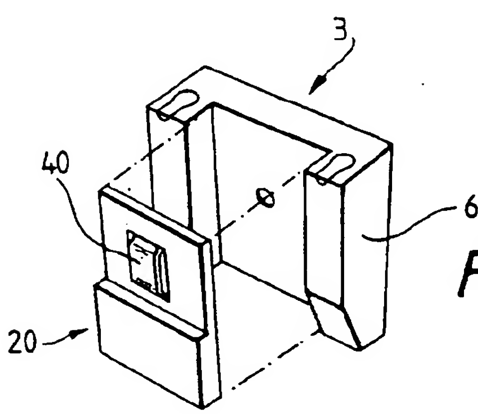


Fig.15.